MYSTERY OF THE LIGHT BULBS

WHY HALF THE CURRENT ISN’T HALF AS BRIGHT

TIMOTHY HEUMIER, PH.D.
MATH/PHYSICS DEPARTMENT
AZUSA PACIFIC UNIVERSITY
The amount of current flowing through a light bulb affects how bright it is. Three identical light bulbs glow dimly with current reduced from what a single light bulb would receive.
Below, each parallel bulb receives 1/2 the current that the series bulb does, yet look closely: the parallel bulbs do not glow!
Mystery Solved!

1. Current adds energy to the filament.
2. Energy elevates temperature.
3. Resistance rises as temperature does.

Graph A
Resistivity of Tungsten

\[ R = R_0 \left( \frac{T}{T_0} \right)^{1.2} \]

\[ y = 0.0059x^{1.2064} \]

\[ R^2 = 0.9999 \]
4. At equilibrium, power in = power out, or joule heating = power radiated.

\[ I^2R = \sigma eA(T^4 - T_0^4) \]

Solving this power balance equation for temperature as a function of current yields the graph below.
5. Higher temperature means more visible optical power. Inset: the detector doesn’t treat all wavelengths equally. As the filament heats up, more of the radiation moves into the detector’s range, just like the eye.
Putting It All Together
Prediction: *Half the current will be much less than half as bright!* 
Insets: It is!

Theoretical Visible Radiated Power

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**Measured Optical Power, Small Bulb**

- **Experimental brightness, 150 W bulb**

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**Experimental brightness, 150 W bulb**

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**Brightness, lux** vs. **Current, amperes**

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